

**U.S. FISH AND WILDLIFE SERVICE
SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM**

SCIENTIFIC NAME: *Cottus* sp., sp. nov.

COMMON NAME: Grotto Sculpin

LEAD REGION: 3

INFORMATION CURRENT AS OF: May 1, 2010

STATUS/ACTION:

☐ Species assessment - determined species did not meet the definition of endangered or threatened under the Act and, therefore, was not elevated to Candidate status

☐ New candidate

☒ Continuing candidate

☐ Non-petitioned

☒ Petitioned - Date petition received: May 11, 2004

☐ 90-day positive - FR date:

☐ 12-month warranted but precluded - FR date:

☐ Did the petition requesting a reclassification of a listed species? No

FOR PETITIONED CANDIDATE SPECIES:

a. Is listing warranted (if yes, see summary of threats below)? Yes

b. To date, has publication of a proposal to list been precluded by other higher priority listing actions? Yes

c. If the answer to a. and b. is "yes", provide an explanation of why the action is precluded.

We find that the immediate issuance of a proposed rule and timely promulgation of a final rule for this species has been, for the preceding 12 months, and continues to be, precluded by higher priority listing actions (including candidate species with lower LPNs). During the past 12 months, most of our national listing budget has been consumed by work on various listing actions to comply with court orders and court-approved settlement agreements, meeting statutory deadlines for petition findings or listing determinations, emergency listing evaluations and determinations, and essential litigation-related, administrative, and program management tasks. We will continue to monitor the status of this species as new information becomes available. This review will determine if a change in status is warranted, including the need to make prompt use of emergency listing procedures. For information on listing actions taken, see the discussion of "Progress on Revising the Lists," in the current CNOR, which can be viewed on our Internet website (<http://endangered.fws.gov/>).

☐ Listing priority change

Former LP: ☐

New LP: ☐

Date when the species first became a Candidate (as currently defined): June 13, 2002

___ Candidate removal: Former LP: ___

___ A – Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.

___ U – Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species.

___ F – Range is no longer a U.S. territory.

___ I – Insufficient information exists on biological vulnerability and threats to support listing.

___ M – Taxon mistakenly included in past notice of review.

___ N – Taxon does not meet the Act's definition of "species."

___ X – Taxon believed to be extinct.

ANIMAL/PLANT GROUP AND FAMILY: Fish; Family Cottidae

HISTORICAL STATES/TERRITORIES/COUNTRIES OF OCCURRENCE: Missouri

CURRENT STATES/ COUNTIES/TERRITORIES/COUNTRIES OF OCCURRENCE: Perry County, Missouri

LAND OWNERSHIP: The entire known range of grotto sculpin is under private ownership, approximately 145,000 acres.

LEAD REGION CONTACT: Jessica Hogrefe, 612-713-5346, Jessica_Hogrefe@fws.gov

LEAD FIELD OFFICE CONTACT: Columbia, Missouri Ecological Services Field Office, Scott Hamilton, 573-234-2132, scott_hamilton@fws.gov.

BIOLOGICAL INFORMATION:

The following information is a summary of observations recorded in Burr et al. (2001), from Ginny Adams, Department of Zoology and Center for Systematic Biology, Southern Illinois University, Carbondale, IL, in litt., February 4, 2002, or Adams, pers. comm., March 7, 2002.

Species Description

The grotto sculpin is a small (approximately 2.5 inches long) fish. Typical of many cave-dwelling species, it is nearly blind and pale-colored.

Taxonomy

The grotto sculpin (*Cottus* sp., sp. nov.) is a relatively small fish within the banded sculpin (*Cottus carolinae*) complex that exhibits distinct cave-adapted features. The banded sculpin complex includes both hypogean (below surface) and epigean (surface, primarily non-cave dwelling) forms. The grotto sculpin is most likely the only hypogean form within the banded sculpin complex and can be distinguished from epigean fish within this complex by several cave-adapted features. These features include smaller, nearly non-functional eyes; reduced skin

pigmentation; smaller optic nerves; larger anterior portion of the brain; fewer pelvic fin rays; and lower metabolic rates, among other features. Although the occurrence of *C. carolinae* in subterranean waters is well known (Poly and Boucher (1996, p. 188; p. 194) and Burr et al. (2001, p. 279) documented the presence of banded sculpins in about 25 caves from several states with known karst environments), none of these sculpins show evidence of cave adaption to the extent exhibited by the grotto sculpin, and none are known to be permanent cave residents. Burr et al. (2001, p. 293) have clearly demonstrated that the grotto sculpin is morphologically distinct from the epigeal forms of banded sculpin. Adams et al. (2003, p. 11) collected data that support the genetic distinctness of the grotto sculpin, although further research is needed before the fish can be formally described.

Habitat/Life History

Grotto sculpin inhabit cave systems, occupying pools and riffles with moderate stream flow and low to moderate stream depth. These fish can be found in the open water or hidden under rocks and occur over a variety of substrates including silt, gravel, cobble, rock rubble that originated from cave breakdown material, or solid bedrock. Rare cave systems formed beneath a sinkhole plain that provides substantial organic input and an abundance of invertebrates may be the only habitats that provide enough food and sustained flow to support sculpin populations. (Burr et al. 2001, p. 291). A recent population ecology study shows that grotto sculpin disappear from resurgence sites after December, which may indicate a subterranean migration for spawning (Day et al. 2008, p. 1). According to this study, young-of-the-year appear between March to May at resurgence sites and from April to May in caves, while adults dominate caves and are found only seasonally at resurgence sites.

Range/Distribution

This species is restricted to two karst (limestone regions characterized by sink holes, abrupt ridges, caves and underground streams) areas, the Central Perryville Karst and Mystery-Rimstone Karst in Perry County, southeast Missouri. Grotto sculpin have been found within three surficial stream systems within Perry County: Blue Springs Branch, Cinque Homes Creek, and Apple Creek (Brad Pobst, pers. comm.). In determining the overall distribution of grotto sculpin, Burr et al. (2001, p. 283) sampled over 27 cave streams within six karst regions in Perry County and documented the species in only five cave systems (Crevice, Moore, Mystery, Rimstone River, and Running Bull/Maple Leaf Cave). To date, over 153 additional caves in Arkansas, Illinois, Indiana, Missouri, and Tennessee have been searched for grotto sculpin and epigeal or hypogean forms of banded sculpin. Of these, *Cottus carolinae* was documented in 25 caves, but only fish in the 5 caves listed above exhibited the cave adaptations reported for grotto sculpin (Burr et al. 2001, p. 284). The current overall range of grotto sculpin has been estimated to encompass approximately 260 square kilometers (100 square miles).

Population Estimates/Status

The total number of grotto sculpin that currently exist is unknown, but based on estimates obtained from Mystery (60 grotto sculpins) and Running Bull Cave (at least 150 grotto sculpins), the population probably does not exceed a few thousand fish (Burr et al. 2001, p. 284). Most studies show that troglomorphic species are found in lower abundances than epigeal fishes. Grotto sculpins have high abundance compared to other cave fishes. Based on a tagging study from August 2005 to January 2008 it is estimated that grotto sculpin abundance is $0.075/\text{m}^2$

within caves (Adams et al. 2008b, p. 5), compared with Ozark cavefish (*Ambloypopsis rosae*) at 0.005-0.15/ m², northern cavefish (*Amblyopsis spelaea*) at 0.05/ m² and southern cavefish (*Typhlichthys subterraneus*) at 0.03/ m². Grotto sculpin densities were much lower in caves (0.075/m²) compared to the surface streams (0.371/m²). Sculpin densities in caves were highest during summer (0.11/m²), followed by fall (0.072/m²), spring (0.071/m²) and finally winter (0.04/m²) (Adams et al. 2008b). On the surface, sculpin densities were highest during summer (0.647/m²), followed by fall (0.37904/m²), spring (0.308/m²), and winter (0.159/m²) (Adams et al. 2008b p. 5). This same study also showed that the majority of recaptured sculpins moved 0-50 meters (68%), which is typical of many benthic species. However, substantial migrations were seen and may be seasonal in relation to spawning.

THREATS:

A. The present or threatened destruction, modification, or curtailment of its habitat or range.

Two caves (Crevice and Moore) containing grotto sculpins are located down-gradient of the city of Perryville, Missouri. Dye trace studies of water movement suggest that urban runoff from Perryville and the surrounding area enters cave streams occupied by grotto sculpins (Burr et al. 2001, p. 294). Industrial-source pollutants, such as phenanthrene and pyrene, were found at moderately high levels within Grotto Sculpin habitat during sampling conducted in 2008 (Fox et. al, 2009 (p. 29) Vandike (1985, p. 38) analyzed the deposition of various agricultural chemicals within the Perryville Karst area and reported detections of ammonia, nitrite/nitrate, chloride, and potassium from cultivation at levels high enough to be detrimental to aquatic life. Fox et. al, 2009 (p. 29) found “pervasive and widespread contamination of Grotto Sculpin habitat by a mixture of bioaccumulative organic contaminants. Dieldrin and heptachlor epoxide were found at levels exceeding national criteria for protection of aquatic life.” Water quality samples collected monthly by the Missouri Department of Conservation (MDC) between December 2007 – 2009 indicate that nitrate/nitrite, phosphorus, atrazine, and acetochlor have been found at high levels from 11 springs and 8 surface streams. At the same time E. Coli samples indicated high levels that may correspond to high inputs of phosphorus from septic systems (Brad Pobst, pers comm.).

Of the five cave systems documented to have grotto sculpins, populations in two cave systems have had fish kills in recent times. Historically Running Bull Cave had the highest density of grotto sculpin (Burr et al. 2001). However, a fish kill occurred in 1999 that resulted in a mass mortality of the observable population and subsequent surveys did not find sculpin until 2005. In 2005, Running Bull Cave was sampled on two different occasions and 9 and 35 individuals were found, respectively (Brad Pobst pers. comm.). It is unknown whether these individuals survived the pollution event in 1999, or if they emigrated from another cave system. This massive fish kill was caused from an unknown source.

In August 2005, there was a major fish kill that eliminated Grotto Sculpins from 69 sections (690 meters) of Mystery Cave (Adams et al. 2008b, p. 6). The population is currently recovering, but is not yet up to previous levels (Brad Pobst, pers. comm.)

B. Overutilization for commercial, recreational, scientific, or educational purposes.

Although some specimens of grotto sculpin have been taken for scientific investigations, such collecting activities do not appear to be at a level that poses a significant threat to this fish.

C. Disease or predation.

Predatory fish occur in all of the caves occupied by the grotto sculpin; these fish are potential predators on the eggs and young of sculpin (Burr et al. 2001, p. 284). The predatory fish found in grotto sculpin caves include: common carp (*Cyprinus carpio*), fat-head minnow (*Pimephales promelas*), yellow bullhead (*Ameiurus natalis*), green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), and channel catfish (*Ictalurus punctatus*) (Burr et al. 2001, p. 284). These potential predators, normally excluded from cave environments, most likely have escaped surface farm ponds that unexpectedly drain through sinkholes into the underground cave systems and enter grotto sculpin habitat. Burr et al. (2001, p. 284) indicates that these escaped fishes have increased the potential predation pressure on grotto sculpin.

D. The inadequacy of existing regulatory mechanisms.

Because the grotto sculpin has not been formally recognized as a distinct taxonomic entity, it is currently not protected under the Missouri State Endangered Species Law 252.240, but it still has some protection under other sections of the Missouri Wildlife Code. The MDC has a ranking system for species of concern. The grotto sculpin is ranked as a S2 which indicates that it is imperilled. The Department maintains two references relating to the status of listed plants and animals in Missouri; the Missouri Species of Conservation Concern Checklist and the Wildlife Code of Missouri. All species in the State of Missouri are protected as biological diversity elements unless a method of legal harvest is described in the Wildlife Code.

The Missouri Department of Natural Resources has the authority for establishing water quality standards that are protective of aquatic life. According to state statutes, it is illegal to dump waste materials into sinkholes. Clean Water Act regulations would apply if a point source for the pollution could be determined. Discrete pollution events that impact cave systems are problematic even if a point source can be determined because it can be extremely difficult to assess damages to natural resources such as troglobitic biota that live underground. Cave systems are recharged by surface and ground water that typically travels several miles before resurfacing from cave openings and spring heads.

E. Other natural or manmade factors affecting its continued existence.

Karst regions are unique in that sinkholes, a significant component of the habitat, allow chemicals and pollutants to reach groundwater directly, without being filtered. Philip Moss (Karst Dye Tracing, Perry County Missouri Finale Report 2010, p. 5) states that household trash is found in at least one sinkhole on nearly every historic farm in the sinkhole plain within Perry County. However, a typical farm has some tens of sinkholes. This can be a significant amount of sinkholes but it is less than half of the sinkholes in Perry County. These sinkholes contain anthropogenic refuse, ranging from household cleansers and sewage to used pesticide containers. As a result, potential water contamination from various sources of point and non-point source pollution poses a significant threat to the grotto sculpin. Additionally, as the city of Perryville

expands closer to grotto sculpin caves, potential threats from these sources of pollution become greater.

The small population size and endemism (i.e., restricted to five cave systems in one county) of the grotto sculpin make it vulnerable to extinction due to genetic drift, inbreeding depression, and random or chance changes to the environment (Smith 1974, p. 350). Inbreeding depression can result in death, decreased fertility, smaller body size, loss of vigor, reduced fitness, and various chromosome abnormalities (Smith 1974, p. 350). Despite evolutionary adaptations for rarity, habitat loss and degradation increase a species' vulnerability to extinction (Noss and Cooperrider 1994, p. 62). Numerous authors (e.g., Noss and Cooperrider 1994, p. 63; Thomas 1994, p. 374) have indicated that the probability of extinction increases with decreasing habitat availability. Although changes in the environment may cause populations to fluctuate naturally, small and low-density populations are more likely to fluctuate below a minimum viable population (i.e., the minimum or threshold number of individuals needed for a population to persist in a viable state for a given interval; Gilpin and Soule 1986, p. 25; Shaffer 1981, p. 132; Shaffer and Samson 1985, p. 150). Current threats to the habitat of the grotto sculpin may exacerbate potential problems associated with its low population numbers and increase the likelihood of extinction.

CONSERVATION MEASURES PLANNED OR IMPLEMENTED:

Although no conservation agreements are currently in place for the grotto sculpin, the Missouri Department of Conservation plans to develop either a State Conservation Agreement or Candidate Conservation Agreement for this fish involving all stakeholders and private land owners in Perry County within the range of the sculpin (Peggy Horner, Endangered Species Coordinator, MDC, Jefferson City, Missouri, pers. comm. 2002).. Before developing a conservation agreement, the State would like to gather more information on point source threats to the grotto sculpin and other information on water quality.

Major Conservation Actions Planned or Implemented by the Missouri Department of Conservation:

1. A high priority action item is to attain information on the drainage area and the connectivity of these cave systems containing the grotto sculpin. To accomplish this objective, \$124,400 has been secured to conduct a recharge delineation study that began in the spring of 2006 and should be completed by June 2010. Water traces have been conducted to obtain groundwater recharge information, recharge delineations and hazards to be mapped within Mystery, Running Bull, Rimstone, Crevice, and Moore Cave systems (Aley and Moss. 2008).
2. Physical parameters were collected every 30 minutes with Hydrolab DataSode 4X and 5X multi-probe units at four permanent cave sites and, when available, at two additional sites from January 2006 thru December 2009. This allows researchers to determine impacts associated with urban and agricultural runoff, livestock waste, and septic runoff in the study area. Parameters measured include: temperature, pH, conductivity, ammonia, depth, turbidity, and dissolved oxygen. Data will be analyzed in 2010 and a report

completed in 2011.

3. Monthly sampling of eleven springs and eight surface streams was conducted from March 2007 thru December 2009. All samples were analyzed for nitrate, nitrite, ammonium, orthophosphate, E. coli, total coliforms, chloride, Atrazine and total suspended sediment. Atrazine was also sampled bi-weekly from April thru July was sampled in 2008-2009.
4. A contaminant assessment was initiated in 2008 using semipermeable membrane devices (SPMD's) and polar organic chemical integrative samplers (POCIS) to evaluate concentrations of potentially harmful chemicals present in cave and surface streams. (Adams et al. 2008a). These samplers are able to sequester trace levels of chemicals during their deployment that are below the method detection limit obtainable with water samples of a few liters. Canisters containing SPMDs and POCIS samplers were deployed at Blue Springs, Mertz Cave, Mystery Resurgence, Thunderhole Resurgence and Cedar Springs. The final report will be completed in June 2010.
5. To better understand the impacts of installing vertical drains in sinkholes by the Perry County Soil and Water Conservation District, a minimum of 40 water samples will be collected from 4 vertical drains and 1 natural sinkhole. This study will provide information on the best BMP's to manage sinkholes.. These samples will be collected from 2009-2011.
6. Funding has been secured to determine the population size, movement, habitat, age, and growth of the grotto sculpin. This project began in 2006. Funding has also been secured to collect DNA samples to analyze and determine the genetic structure of the grotto sculpin. This study is expected to be completed in 2010.
7. A video titled "Cave Sculpin" was developed and aired on the weekly television program Missouri Outdoors. This video is about the grotto sculpin and potential water quality issues that are unique to the karst environment found in Perry County. The video will also be shown in local schools to educate students and at landowner workshops in Perry County.
8. In conjunction with a Clean Water Act section 319 grant, Missouri Department of Conservation will work with landowners to develop a cost share program to clean out trash laden sinkholes. In 2009, the Service allocated an additional \$20,000 to clean out additional sinkholes. Two sinkholes were cleaned out in October 2006 and May 2009 respectively. There are plans to clean out 10 additional sinkholes by December 2011. MDC will conduct one landowner workshop each year from 2008-2010. These workshops will provide information on the dye tracing and water quality studies and provide technical recommendations on how to protect sink holes and the karst environment. Two workshops have been completed to date.
9. MDC will work with other agencies to develop Best Management Practices and secure funding to manage sinkholes on private land.

10. MDC will work with the grotto clubs and invite them to participate in the recovery effort.
11. From 2008-2010, local agencies and sponsors will conduct a water festival each year that will teach every 5th grade student in Perry County the importance of protecting the karst environment that they live on.

SUMMARY OF THREATS:

The Grotto sculpin is restricted to two karst areas (limestone regions characterized by sink holes, abrupt ridges, caves and underground streams), the Central Perryville Karst and Mystery-Rimstone Karst in Perry County, southeast Missouri. Grotto sculpin have been documented in only five cave systems. The current overall range of grotto sculpin has been estimated to encompass approximately 260 square kilometers (100 square miles). The small population size and endemism of the grotto sculpin make it vulnerable to extinction due to genetic drift, inbreeding depression, and random or chance changes to the environment. The species karst habitat is located down-gradient of the city of Perryville, Missouri, which poses a potential threat if contaminants from this urban area enter cave streams occupied by grotto sculpins. Various agricultural chemicals, such as ammonia, nitrite/nitrate, acetochlor, dieldrin, and atrazine, have been detected at levels high enough to be detrimental to aquatic life within the Perryville Karst area. At least one sinkhole on every farm in Perry County contains anthropogenic refuse, ranging from household cleansers and sewage to used pesticide and herbicide containers. As a result, potential water contamination from various sources of point and non-point pollution poses a significant threat to the grotto sculpin. Two of the five known cave systems with grotto sculpins experienced massive mortality in the last 10 years, presumably from point source pollution. Predatory fish such as common carp, fat-head minnow, yellow bullhead, green sunfish, bluegill, and channel catfish occur in all of the caves occupied by grotto sculpin. These predators may escape surface farm ponds that unexpectedly drain through sinkholes into the underground cave systems and enter grotto sculpin habitat. The only regulatory mechanism in place that would provide protection to the grotto sculpin is through the Missouri Department of Conservation Wildlife Code. Current threats to the habitat of the grotto sculpin may exacerbate potential problems associated with its low population numbers and increase the likelihood of extinction. We find that this species is warranted for listing throughout all its range, and, therefore, it is unnecessary to analyze whether it is threatened or endangered in a significant portion of its range. Due to the high magnitude of threats that are imminent, we assign this species a listing priority number of 2.

For species that are being removed from candidate status:

___ Is the removal based in whole or in part on one or more individual conservation efforts that you determined met the standards in the Policy for Evaluation of Conservation Efforts When Making Listing Decisions (PECE)?

RECOMMENDED CONSERVATION MEASURES:

Promote and encourage landowners to enroll in the many cost share vegetation buffer practices through government agencies. This would include the CP33 (Habitat Buffers for Upland Birds), CP22 (Riparian Buffers), and CP21 (Filter Strips) through the Farm Service Agency, the

EQUIP and WHIP programs through NRCS, the cost share practices through the Perry County SWCD, and the Missouri Department of Conservation in the Perry County karst. The goal is to combine resources from different agencies that will allow establishment of riparian buffers/cattle exclusion and/or filter strips for three miles of stream and ten sinkholes within the next four years. High levels of nutrient runoff can be significantly reduced through buffer strip management (Ducnuigee et al. 1997, p. 9).

Reduce application of agricultural chemicals within the karst plain that can impact water quality and the health of the Grotto Sculpin via enrollment in cost-share programs, such as nutrient management plans, or other means.

Clean out trash-laden sinkholes and haul off debris to appropriate landfill. The sinkholes sometimes harbor chemical containers or solid waste that can migrate into the underground system and degrade the health of the underground ecosystem..

LISTING PRIORITY:

THREAT			
Magnitude	Immediacy	Taxonomy	Priority
High	Imminent	Monotypic genus	1
		Species	2*
	Non-imminent	Subspecies/population	3
		Monotypic genus	4
		Species	5
		Subspecies/population	6
Moderate to Low	Imminent	Monotypic genus	7
		Species	8
		Subspecies/population	9
	Non-imminent	Monotypic genus	10
		Species	11
		Subspecies/population	12

Rationale for listing priority number:

Magnitude and Immanency

The pollution events that resulted in killing sculpins in Running Bull and Mystery Caves suggests that the threat from chemical contamination is immediate and of a high magnitude. Furthermore, as noted above, there is evidence (Fox et. al, 2009 (p. 29)) that this area is highly susceptible to additional sources of contamination that threaten the remaining populations. Burr et al. (2001, p. 294) and local Conservation Department staff have noted that many of the sinkholes in Perry County contain anthropogenic refuse, ranging from household cleansers and sewage, to used pesticide and herbicide containers, providing further evidence of the high

magnitude and imminent threats to this species from chemical contamination. Further compounding the threats to the grotto sculpin are potential predation from predatory fish, developmental pressures from the nearby city of Perryville, and loss of genetic diversity.

Yes Have you promptly reviewed all of the information received regarding the species for the purpose of determining whether emergency listing is needed?

Is Emergency Listing Warranted? Emergency listing is not warranted at this time. Although the magnitude and immediacy of threats to the grotto sculpin are high, expected losses to populations during the normal listing process would not risk the continued existence of the entire species or loss of significant recovery potential.

DESCRIPTION OF MONITORING:

The Missouri Department of Conservation was contacted in May 2010 to review the latest species assessment and to provide any new information. MDC has regular contact and project coordination with species experts at the University of Central Arkansas and they also provided updated research results. Data is being collected on population size, movement, habitat, age and growth, and genetic makeup of the species. A population ecology study was completed in 2008 by graduate students at the University of Central Arkansas and the results are included this CNOR. The MDC has also established a long term water quality monitoring project with other agencies and local entities that will provide useful information on habitat quality and threats. This contaminant assessment report is expected to be completed in 2010.

Very little is known about grotto sculpins and the monitoring that is planned and/or ongoing will be beneficial in describing the species, continuing to update the status and applying the proper management. Prior to the population ecology study nothing was known about the seasonal movements of grotto sculpins. The study also provides some data on population densities. Water quality monitoring will provide data on several parameters and identify potential pollution sources. A recharge delineation study scheduled for completion in 2010 will reveal connectivity of the cave systems and allow mapping of recharge areas where management practices can be implemented.

COORDINATION WITH STATES:

Indicate which State(s) (within the range of the species) provided information or comments on the species or latest species assessment: Missouri

Indicate which State(s) did not provide any information or comments: None

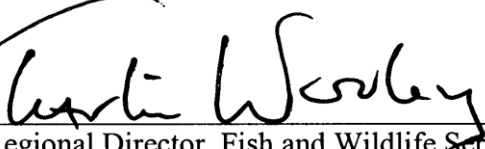
The Perry karst system is currently included in the State Wildlife Action Plan as part of the River Hills Conservation Opportunity Area (COA). The Perry County Karst Area is currently being considered as an independent COA.

LITERATURE CITED:

- Adams, G., d. Keeney, B.M. Burr. 2003. Population genetics of grotto sculpin, *Cottus carolinae*, in Perry County, Missouri. Report to the U.S. Fish and Wildlife Service, Columbia, Missouri. 22pp.
- Adams, G., J. Fox, K. Steelman. 2008a. Contaminant Concentration Analysis in Streams Utilized by Grotto Sculpin (*Cottus carolinae*) in Perry County, Missouri. University of Central Arkansas. Progress reported submitted to Missouri Department of Conservation and Perry County Soil and Water Conservation District. 18 pp.
- Adams, G., J. Day, J. Gerken, and C. Johnson. 2008b. Population Ecology of the Grotto Sculpin, *Cottus carolinae*, in Perry County, Missouri. University of Central Arkansas. Progress Report submitted to Missouri Department of Conservation. 25 pp.
- Aley, T. and P. Moss. Karst Dye Tracing Perry County, Missouri. Progress Report 1. Ozark Underground Laboratory. Progress report submitted to the Perry County Soil and Water Conservation District. 33pp.
- Burr, B.M., G.L. Adams, J.K. Krejca, R.J. Paul, and M.L. Warren, Jr. 2001. Troglomorphic sculpins of the *Cottus carolinae* species group in Perry County, Missouri: distribution, external morphology, and conservation status. *Environ. Bio. of Fishes* 62:279-296.
- Day, Julie L., Clint R. Johnson, Joseph E. Gerken, Ginny Adams. 2008. Population Ecology of Grotto Sculpin (*Cottus carolinae*) in Cave and Resurgence Streams. Department of Biology, University of Central Arkansas, Conway AR; USGS Fish & Wildlife Cooperative Research Unit, Kansas State University, Manhattan KS. Poster presentation American Fisheries Society. 1p.
- Ducnuigeen, Jan, Karl Williard, Roland C. Steiner. 1997. Relative Nutrient Requirements of Plants Suitable for Riparian Vegetated Buffer Strips. Virginia Department of Environmental Quality, Interstate Commission on the Potomac River Basin. Report No. 97-4. 17pp + appendices.
- Fox, K., Adams, G., J., Steelman. 2009. Contaminant Concentration Analysis of Perry County, Missouri Cave Streams Utilized by Grotto Sculpin (*Cottus carolinae*). University of Central Arkansas. Final report submitted to Missouri Department of Conservation and Perry County Soil and Water Conservation District. 51 pp.
- Gilpin, M.E., and M.E. Soule. 1986. Minimum viable populations: The processes of species extinctions. Pages 13-34 in *Conservation Biology: The Science of Scarcity and Diversity*, M.E. Soule, (ed.). Sinauer Associates, Sunderland, Mass.
- Noss, R.F., and A.Y. Cooperrider. 1994. Saving nature's legacy. Protecting and restoring biodiversity. Island Press, Washington, D.C.

- Poly, W.J. and C.E. Boucher. 1996. Nontroglobitic fishes in caves: their abnormalities, ecological classification and importance. *Amer. Midl. Nat.* 136:187-198.
- Shaffer, M. L. 1981. Minimum population sizes for species conservation. *BioScience* 31:131-134.
- Shaffer, M.L., and F.B. Samson. 1985. Population size and extinction: a note on determining critical population size. *American Naturalist* 125:144-152.
- Smith, R.L. 1974. *Ecology and Field Biology*. Second Edition. Harper & Row, New York, N.Y. 850 pp.
- Thomas, C.D. 1994. Extinction, colonization, and metapopulations: environmental tracking by rare species. *Conservation Biology* 8(2): 373-378.
- Vandike, J.E. 1985. Movement of shallow groundwater in the Perryville Karst area, southeastern Missouri. *Water Res. Rept.* (40):1-56.

APPROVAL/CONCURRENCE: Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

Approve: 
ACTING Regional Director, Fish and Wildlife Service

6/2/10
Date

Concur: 
ACTING
Director, Fish and Wildlife Service

Date: October 22, 2010

Do not concur _____
Director, Fish and Wildlife Service

Date

Director's Remarks:

Date of annual review:
Conducted by:

Comments: